Research Title: Exploiting V2X Connections and Advanced Energy Management Strategies to Achieve Maximum CO2 Reductions from Hybrid Electric Vehicles

Funded by DIPARTIMENTO ENERGIA

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Context of the research activity

Nowadays powertrain hybridization represents one of the most promising ways towards a more sustainable mobility and to achieve the GHG emissions reduction goals set in 2015 at the United Nations Climate Change Conference in Paris [1]. Nevertheless, the fuel economy potential of Hybrid Electric Vehicles (HEVs) strongly depends not only on their electrification level, but also on their Energy Management System (EMS) [2-3]. As a matter of fact, the choice among all the possible exploitations of the different energy sources available on board depends on the actual objective of the hybridization and could be defined through different optimization algorithms [4]. Currently most of energy management strategies rely on heuristic control techniques, which can be easily implemented in powertrain control units, but can achieve performance quite far from the optimality. On the other hand, global optimization techniques can ensure the achievement of the optimal solution in terms of fuel or energy consumption minimization, but require the a priori knowledge of the vehicle driving schedule and cannot be therefore implemented in powertrain control units.

However, the capacity of the vehicle to be connected with the surrounding environment is now providing the chance to know the future (in terms of vehicle driving schedule, of course), thus paving the way to new exploitations of global optimization techniques such as Dynamic Programming to define not only the optimal energy management, but rather the optimal driving schedule of the vehicle, thus achieving unprecedented results in terms of fuel economy and CO2 emissions reductions [5].
In this framework the proposed research activity aims to assess, through numerical simulation, the potential in terms of CO₂ emissions reduction of a synergic use of global optimization techniques, cloud computing and V2X information. The optimization problem will no more only focus on the definition of the energy management of an HEV, but it will also address the selection of a proper route and the definition of the optimal vehicle speed schedule depending on external boundary conditions (e.g. traffic), to achieve the maximum reduction of CO₂ emissions.

![Figure 1: Integrated EMS Information Flow](image)

The research project will be mainly carried out at Politecnico di Torino and in particular in the e3 Research group ([www.polito.it/engines](http://www.polito.it/engines)) of the Energy Department, which can boast a well-reasoned expertise on the optimization of the Energy Management System of HEVs, earning an international recognition of its work which culminated in the Honda Initiative Grant Europe Prize that honored its CAYMAN, Computer Aided development of energy MANagement systems for Hybrid Electric Vehicles as the best powertrain research project from a European University for 2011.

Furthermore, the PhD candidate will also benefit of well-established collaborations with leading universities and research centres, such as the Center of Automotive Research at the Ohio State University ([https://car.osu.edu](https://car.osu.edu)) and the Stanford University ([https://www.stanford.edu](https://www.stanford.edu)) which will offer to the student a 6-months internship in order to further enhance its expertise on the optimization of the Energy Management System of HEVs.

Finally, the PhD candidate will have the chance to participate to a research project on this topic which has been proposed for 2019 within the framework of the partnership agreement between FCA and Politecnico di Torino.
This research activity is aiming at the development of a comprehensive methodology capable of optimizing the operations of a Hybrid Electric Vehicle in terms of overall CO₂ emissions minimization, by exploiting the information available through V2X connections.

Although several works, available in the scientific literature, have already proposed procedures to design sub-optimal Energy Management Systems for HEVs, this research activity has the ambitious target of pushing a step forward the state of the art, towards the achievement of the global optimum. As a matter of fact, the minimization of the overall (i.e. considering also the recharging phase from the grid) CO₂ emissions of the vehicle will be achieved through a synergic use of global optimization techniques, cloud computing, and V2X information. The optimization problem will be expanded from the definition of the energy management of an HEV, to the choice of the optimal route, the definition of the optimal vehicle speed schedule and of the most convenient schedule for the recharging phase from the grid, to achieve the maximum reduction of the overall CO₂ emissions.

A crucial task will be the development of a simulation platform to create a virtual test rig for the assessment of the performance and of the robustness of the proposed methodology.
SCHEDA PER BORSE A TEMATICA VINCOLATA

Additional sub-objectives will be:

- Internship(s) of the PhD candidate at one (or both) US partner universities (likely 6 months);
- Publication of at least one paper and one multidisciplinary paper in high-impact peer-reviewed international journals.

The following break-down of the activities is proposed:

- Extensive literature review on the main global optimization algorithms (3 months);
- Analysis of the main features of the ADAS systems and evaluation of their possible contribution to EMS optimization (3 months);
- Development of a simulation platform to create a virtual test rig for the assessment of the performance and of the robustness of the proposed methodology (6 months);
- Development of a comprehensive methodology to optimize the operations of a Hybrid Electric Vehicle exploiting V2X (1 year);
- Assessment of the proposed methodology on a test case plug-in hybrid architecture:
  - Definition of proper optimization scenarios (urban, suburban...) (3 months)
  - Definition of the optimal route/speed profile and of the best powersplit (3 months)
- Thesis and scientific papers writing (6 months),

Relevant publications of the proponents:


Skills and competencies for the development of the activity

- Fundamentals of powertrain engineering and in particular of hybrid electric vehicles.
- Matlab/Simulink programming.
- Knowledge of 1D/0D CFD simulation codes (such as GT-Suite) would be a plus.